AIR QUALITY TRENDS IN ONTARIO 1971-1976

January 1978

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Ministry
of the
Environment

The Honourable
Harry C. Parrott, D.D.S.,
Minister

K.H. Sharpe,
Deputy Minister

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1971 - 1976

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Ontario Ministry of the Environment
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AIR QUALITY TRENDS IN ONTARIO
1971 - 1976

With the passage of the Air Pollution Control Act(1967), the Province of Ontario embarked upon a program of emission source regulation to meet the desirable ambient air quality criteria set forth in the Act. To document the effectiveness of emission regulation, an extensive network of ambient air monitors was established across the province. Through the years, the network has been altered in response to the needs of the monitoring program. With the data collected during the period 1971 to 1976, the concentration trends for seven pollutants have been determined.

The Ontario Air Quality Monitoring Network

The regular monitoring of atmospheric pollutants began in Ontario in the early 1960's in the Metropolitan Toronto area. With the passage of the Air Pollution Control Act of 1967, the task of air pollution control was centralized in an agency of the provincial government. At that point, the monitoring program began its expansion across the province.By the time of the enactment of The Environmental Protection Act in 1971, the number of sensors had reached nearly 250 for continuous monitoring of gases and total suspended particulate. By 1976, the number of these sensors exceeded 370 (Figure 1).

Extensive monitoring of seven pollutants has taken place during the period 1971 to 1976. These are total suspended particulate, soiling index, sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone, and total hydrocarbons. The growth of the monitoring network for these pollutants is shown in Figure 2. The total number of these monitoring instruments has increased by 53% in the six year period.

Ambient Air Quality Criteria in Ontario

The current Ontario desirable ambient air quality criteria for six of the seven pollutants whose trends will be discussed below are given in Table 1. As yet, no criteria have been established for total hydrocarbons. The percentage of stations meeting criteria during each year of the survey is treated below by individual pollutant.

Graphical Display of Air Quality Trends

The concentration trends for each of seven pollutants are analyzed in this study. To present the information representing the distribution of air quality data, a graphical technique known as the Box Plot is employed. The plotting convention for the Box Plot is displayed in Figure 3. For a given pollutant, the annual averages (or geometric mean in the case of total suspended particulate) of all measuring stations are grouped and then ranked. From this ranking, the 10, 25, 50 (median) 75, and 90 percentile levels are determined. These indicate the percentage of stations cleaner than the plotted value. For example, if the 25 percentile is 17 units, 25% of the stations measuring this pollutant have an annual average less than or equal to 17 units. The composite average of the stations in a given year is also plotted.

The 10 and 25 percentiles typify the trend of the "cleaner sites" in the sample. The average and median may be thought of as depicting average sites, while the 75 and 90 percentiles typify the "dirtier sites" - those with the highest annual averages. Note, however, that these descriptive terms refer only to the distribution of sites within the sampling network for that pollutant, and "cleaner" or "dirtier" sites may exist elsewhere.

Total Suspended Particulate Trends in Ontario

Total suspended particulate (TSP) has many sources both natural and man-made. Measurement of TSP in Ontario is by the standard high volume sampler. Sampling rates vary in Ontario.

Stations sample daily, once every three days, or once every six days. The geometric mean rather than the average is used in the analysis.

The TSP history (Figure 4) shows a significant decline between the years 1973 and 1974 for all plotting positions. Since 1974, the decline in the median value has continued while other plotting positions show changes characteristic of the approach of a steady level. The decrease in TSP by 1976 over 1971 is on the order of 33% for all plotting positions.

The TSP monitoring network increased during the period by 63%. Changes of location within the network left 56 of the 84 1971 stations unaltered by 1976. Because of the large number of new stations in the sample, the set of sites with a complete history from 1971 to 1976 was chosen for separate analysis. These 24 stations represented the effects of pollution controls in 19 cities. Like the full sample, the trend for the selected sites (Figure 5) is characterized by a sharp drop between 1973 and 1974. Levels from 1974 to 1976 have remained nearly steady. This applies especially to the "dirtier" sites. "Cleaner" sites show a slower decline through the six years. TSP at selected sites show a decrease of around 33-35% for all plotting percentiles over the period.

Air quality criteria for TSP are based upon daily and annual averaging periods. The percentage of stations meeting the annual criterion of 60 ug/m^3 geometric mean is shown in Figure 6a. In 1971, only 11% met the criterion. By 1976, however this figure had grown to 52% of the sites. The percentage of stations meeting the 24-hr criterion of 120 ug/m^3 has increased since 1971 to 9% in 1976 (Figure 6b). Natural sources and long-range transport of particulate are significant contributors to measured TSP. Daily levels can, therefore, be significantly influenced by meteorological factors such as precipitation and wind speed, and thus, it is not surprising to see large fluctuations in the number of daily TSP values exceeding the criterion from year to year. During the period of study, the average number of exceedences per station varied from a maximum of 20.3 in 1974 to a minimum of 12.2 the next year.

Soiling Index Trends in Ontario

The soiling index (SI) is a relative measure of suspended particulate based upon the optical transmission density of a sample of particulate matter deposited on the filter. The measure, therefore, is related not only to the amount of particulate but also its physical properties such as its opacity. The unit of measure is the Coefficient of Haze (COH) per 1000 feet of air sampled.

The box plots for SI show a slight decline in the annual arithmetic average although the trend (Figure 7) is neither as distinct nor smooth as that for TSP. Cleaner sites, the 25 and 10 percentile improved only 8% while the 75 percentile improved 21%. The median was nearly unchanged, improving by 4% while the ensemble average showed a decrease of 15%.

The SI monitoring network showedsome slight variation in the number of instrument sites before 1975. The addition of stations in 1975 and 1976 brought an increase in the network of 14%. Stations with continuous records through the six years accounted for 60% of the 1971 network. Analysis of selected sites for SI trends showed no significant difference from the full network except at the 75 percentile where the decrease was 2%.

Stations meeting the annual soiling index criterion of 0.50 varied from 80% to 98% (Figure 8a). The greatest improvement came during 1972-73 when the percentage of stations in excess of the criterion dropped from 15% to 4%. The 24-hr. criterion of 1.0 was exceeded by 66% of the stations in 1971. The percentage dropped to 46% in 1972 and has remained around the 50% mark in succeeding years (Figure 8b).

Trend of Sulphur Dioxide in Ontario

Sulphur dioxide (SO_2) in Ontario has shown a very significant decrease in concentration over the period of this study. Levels in 1976 are nearly 50% lower for the average and high percentile sites than in 1971 (Figure 9). Sites at the 25 and 10 percentiles show decreases of 38% and 17% respectively in 1971. The decrease, however, occurred generally in the years 1972 and 1973, changes being 24% and 62% respectively for the median value. Since 1973, the median levels have oscillated around .010 ppm.

The size of the SO_2 monitoring network has varied from year to year. At present, the network is 22% larger than in 1971. A selection of critical sites with a full history during the period of study has been chosen. The trend for these 14 sites is shown in Figure 10. Again, the pattern shows a significant decrease by 1973 and oscillation thereafter. Percent decreases are over 50% for those stations with higher levels and 33% to 41% at those with lower annual concentrations.

The percentages of stations meeting the SO_2 criteria of 0.25 ppm for 1-hr, 0.10 ppm for 24-hr, and 0.02 ppm for an annual average are shown in Figure 11. All show patterns similar to the trend of the averages, a decrease in exceedences (increase in number of stations meeting criterion) for the first two years and a stabilization thereafter. Nearly 50% of the stations now meet the 1-hr criterion, 75% the 24-hr. criterion, and 85% the annual criterion. This is an improvement of 25%, 29% and 42% for the 1-hr, 24-hr, and 1-yr criteria respectively over 1971. The number of times the criteria has been exceeded has been reduced by 34% for the 1-hr value and 68% for the 24-hr limit in 1976.

Carbon Monoxide Trends in Ontario

Carbon monoxide (CO) is almost exclusively the result of exhaust emissions from vehicles. Although pollution control devices have reduced CO emissions from individual cars and trucks, the increase in their numbers has, in some areas, tempered this reduction.

The trend of CO (Figure 12) shows a great deal of variability in concentration as well as the number of monitoring stations. Since 13 of the 16 sites reporting in 1971 were in the monitoring network in 1976, the change based upon these two years alone should given an accurate picture. The sites at the 90 percentile showed the largest decrease 68% indicating that traffic volume may have been near capacity and the decrease was due to emission control. By comparison, the 10 percentile showed a decrease of 40%. The difference in the improvement at these locations is probably due to a greater increase in traffic density at the lower concentration stations.

Stations meeting the 8-hr criterion of 13 ppm reached the limit of 100% in 1972 and 1976 (Figure 13). The fewest sites meeting criterion came in 1971 when only 69% did not exceed 13 ppm over 8 hours. The 1-hr criterion has only been exceeded once in the six years of this study.

Trends of Total Hydrocarbon in Ontario

Sources for hydrocarbons include natural sources such as trees and other vegetation and man-made sources such as automotive emissions, and petroleum producing and handling facilities. The method of analysis utilized up to 1976, flame ionization, allowed no distinction of hydrocarbon species. Thus, hydrocarbons have been reported as total hydrocarbons. No criteria have been set for total hydrocarbons.

Total hydrocarbons in Ontario (Figure14) show no trend, only a slight oscillation. The change from 1971 to 1976 shows an increase of about 10% at the high percentiles and decrease of 5 - 8% at the lower percentiles.

Trend of Nitrogen Dioxide in Ontario

Regular nitrogen dioxide (NO_2) measurements by chemiluminescent method began in Ontario in 1974. The trend over the three years shows no regular pattern (Figure 15). Percent changes from 1974 to 1976 varied from an increase of 17% at the 50 percentile to a decrease of 29% at the 10 percentile. The ensemble average showed a slight decrease (7%).

Exceedences of the 1-hr criterion of 0.20 ppm increased in frequency in 1975 and decreased in 1976 from 1974 (Figure 16a). The 24-hr criterion exceedences had a similar pattern (Figure 16b).

Trend of Ozone in Ontario

Ozone as well as other oxidants are essentially derived from the photochemical reaction of hydrocarbons and nitrogen oxides in the atmosphere. In 1973, an instrument using chemiluminescence techniques to measure ozone specifically became available. By the end of 1974, it had been installed at eight monitoring sites in Sotuhern Ontario.

The trend of ozone for the 1974 to 1976 period is shown in Figure 17. Variation exists but no trend is apparent. Ozone formation is very dependent upon weather conditions, especially sunlight and temperature. Therefore, differences from year to year will reflect weather variations as well as changes in precursor emissions.

Exceedences of the 1-hr ozone criterion are frequent. Only one station met the criterion in 1975; no stations met the criterion in 1974 or 1976.

SUMMARY

With the enactment of the Air Pollution Control Act in 1967, Ontario embarked upon a program of emission controls to meet desirable levels of ambient air quality. A province-wide air monitoring network was established and expanded. During the period 1971 to 1976, the number of suspended particulate and continuous gas monitors increased by 48%.

Total suspended particulate was found to have decreased by 33% across the province during the six-year sample. The number of stations meeting ambient air quality criteria for total suspended particulate has increased. Soiling index, another measure of suspended particulate matter, showed an improvement of about 15% for the annual average levels. The percentage of stations meeting the criteria also increased.

Sulphur dioxide has decreased by nearly 50% since 1971. Levels fell dramatically by 1973 and have begun to stabilize thereafter at around 0.010 ppm. The percentage of stations meeting the criteria levels have increased.

Carbon monoxide levels have shown a decrease of up to 68% in 1976 as compared to 1971. All stations have met the criteria in 1976.

Nitrogen dioxide and total hydrocarbons showed no trend over the period of measurement. Ozone also showed a similar lack of pattern over a three year span.

LIST OF FIGURES

Figure 1. Growth of Ontario air quality monitoring network.

Figure 2. Growth of Ontario air quality monitoring network for seven selected pollutants.

Figure 3. Concentration box plot plotting levels.

Figure 4. Trend of total suspended particulates in Ontario,1971 to 1976.

Figure 5. Trend of total suspended particulate in Ontario for selected sites, 1971 to 1976.

Figure 6. Percentage of sites meeting total suspended particulate criteria in Ontario, 1971 to 1976: a) annual criterion, b) 24-hour criterion.

Figure 7. Trend of soiling index in Ontario, 1971 to 1976.

Figure 8. Percentage of sites meeting soiling index criteria in Ontario, 1971 to 1965: a) annual criterion, b) 24-hour criterion.

Figure 9. Trend of sulphur dioxide in Ontario, 1971 to 1976.

Figure 10. Trend of sulphur dioxide in Ontario for selected sites, 1971 to 1976.

Figure 11. Percentage of sites meeting sulphur dioxide criteria in Ontario 1971 to 1976: a) annual criterion, b) 24-hour criterion, c) 1-hour criterion.

Figure 12. Trend of carbon monoxide in Ontario, 1971 to 1976.

Figure 13. Percentage of sites meeting carbon monoxide 8-hour criterion in Ontario, 1971 to 1976.

Figure 14. Trends of total hydrocarbons in Ontario, 1971 to 1976.

Figure 15. Trend of nitrogen dioxide in Ontario, 1974 to 1976.

Figure 16. Percentage of sites meeting nitrogen dioxide criteria in Ontario, 1974 to 1976: a) 1-hour criterion, b) 24-hour criterion.

Figure 17. Trend of ozone in Ontario, 1974 to 1976

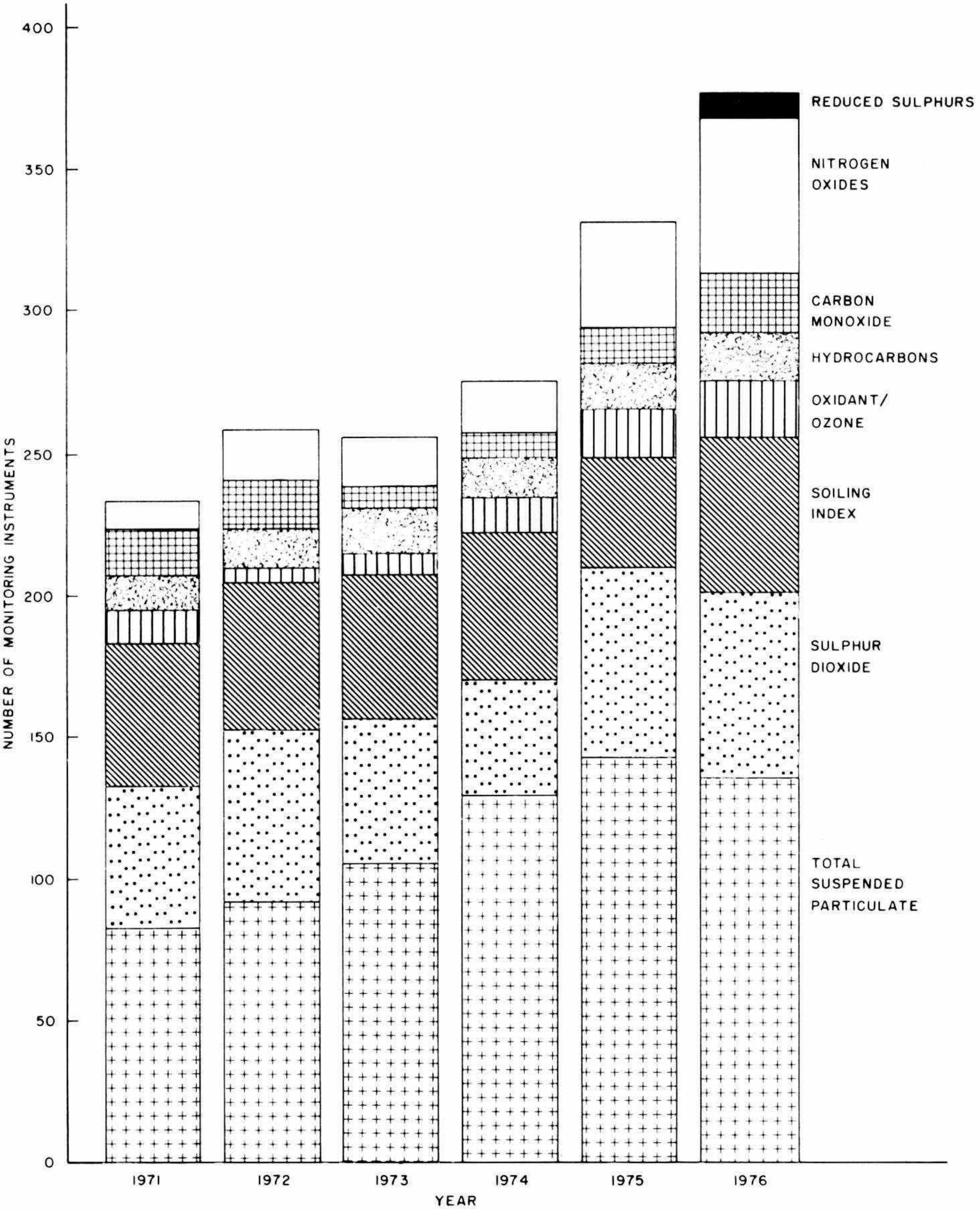

FIGURE I GROWTH OF ONTARIO AIR QUALITY MONITORING NETWORK

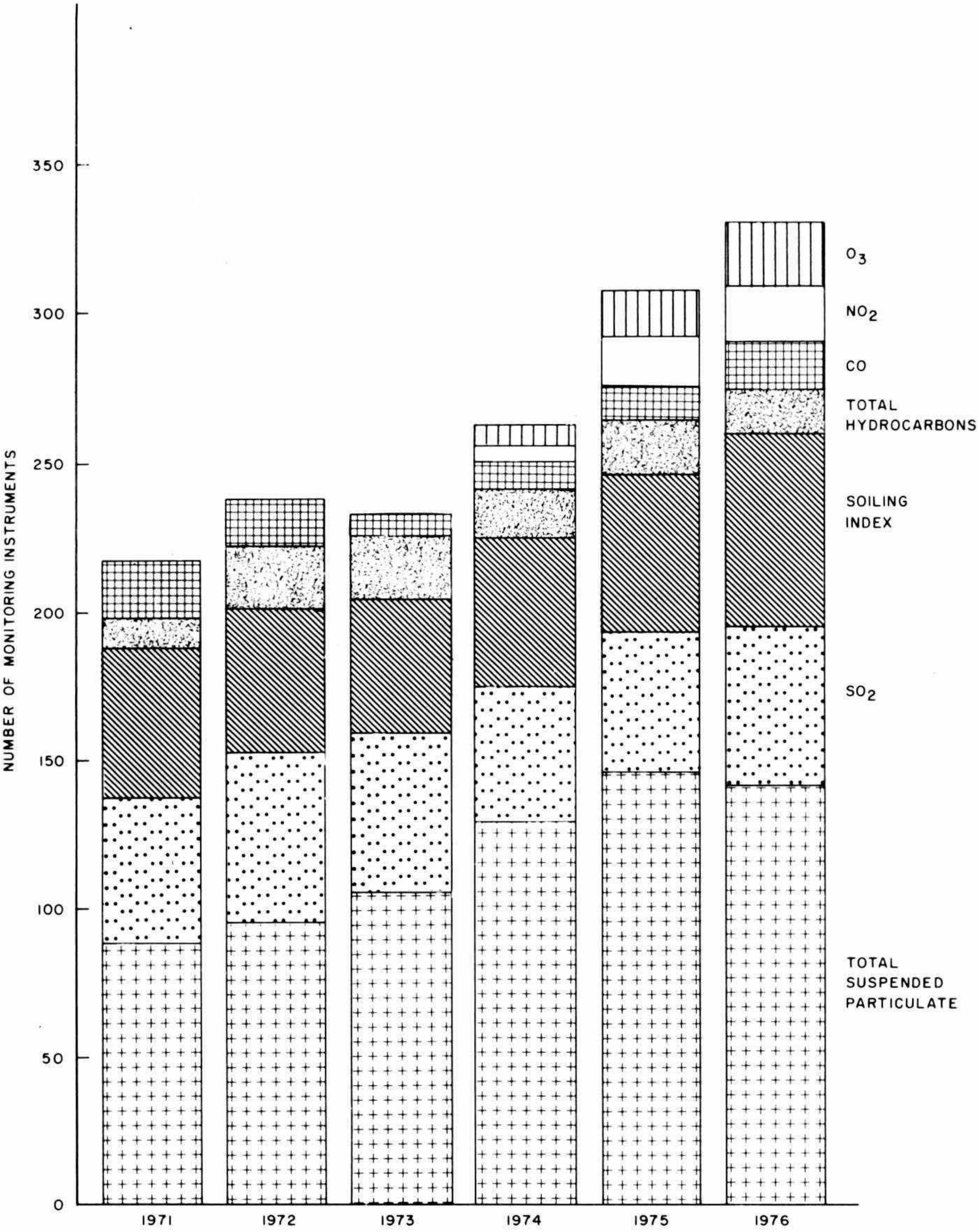

FIGURE 2 GROWTH OF ONTARIO AIR QUALITY MONITORING NETWORK FOR SEVEN SELECTED POLLUTANTS

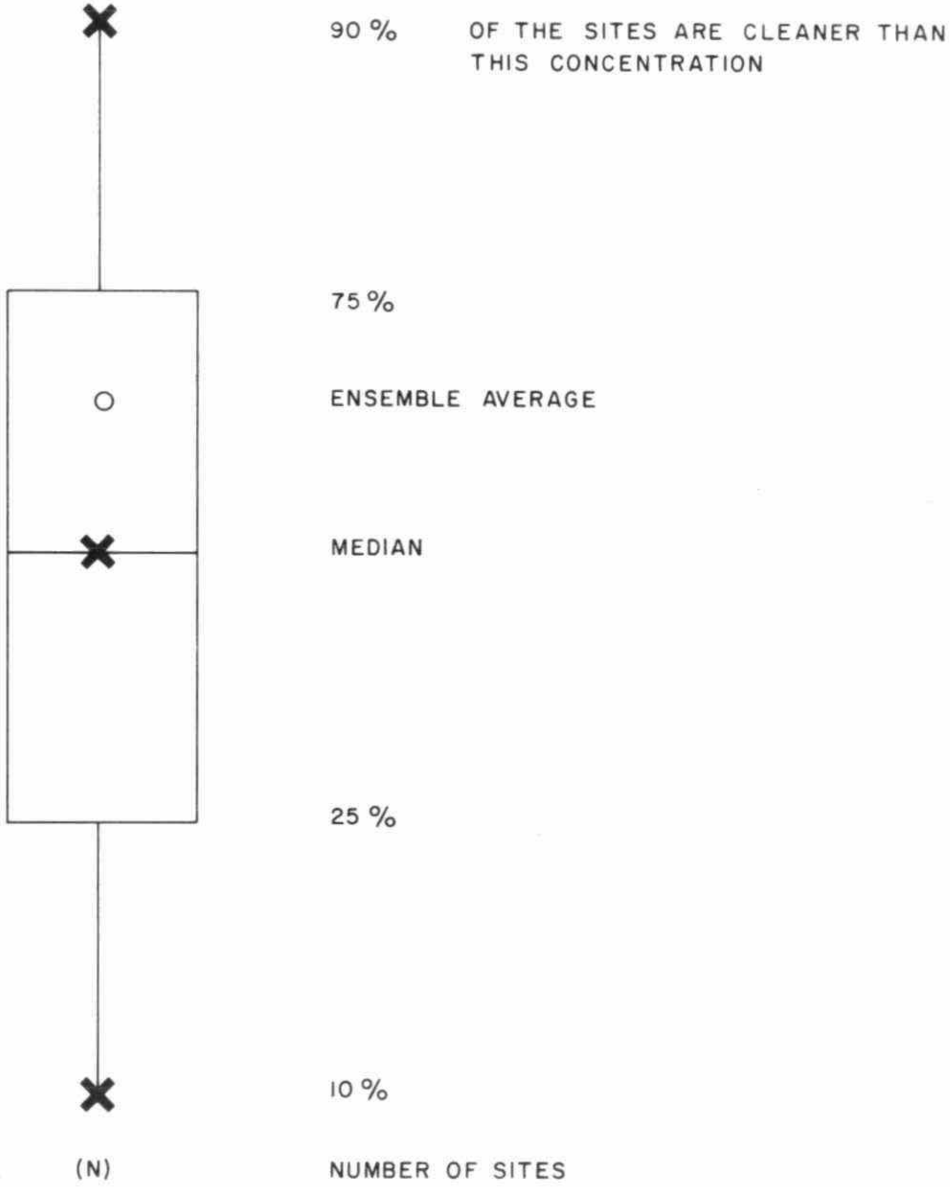

FIGURE 3 CONCENTRATION BOX PLOT PLOTTING LEVELS

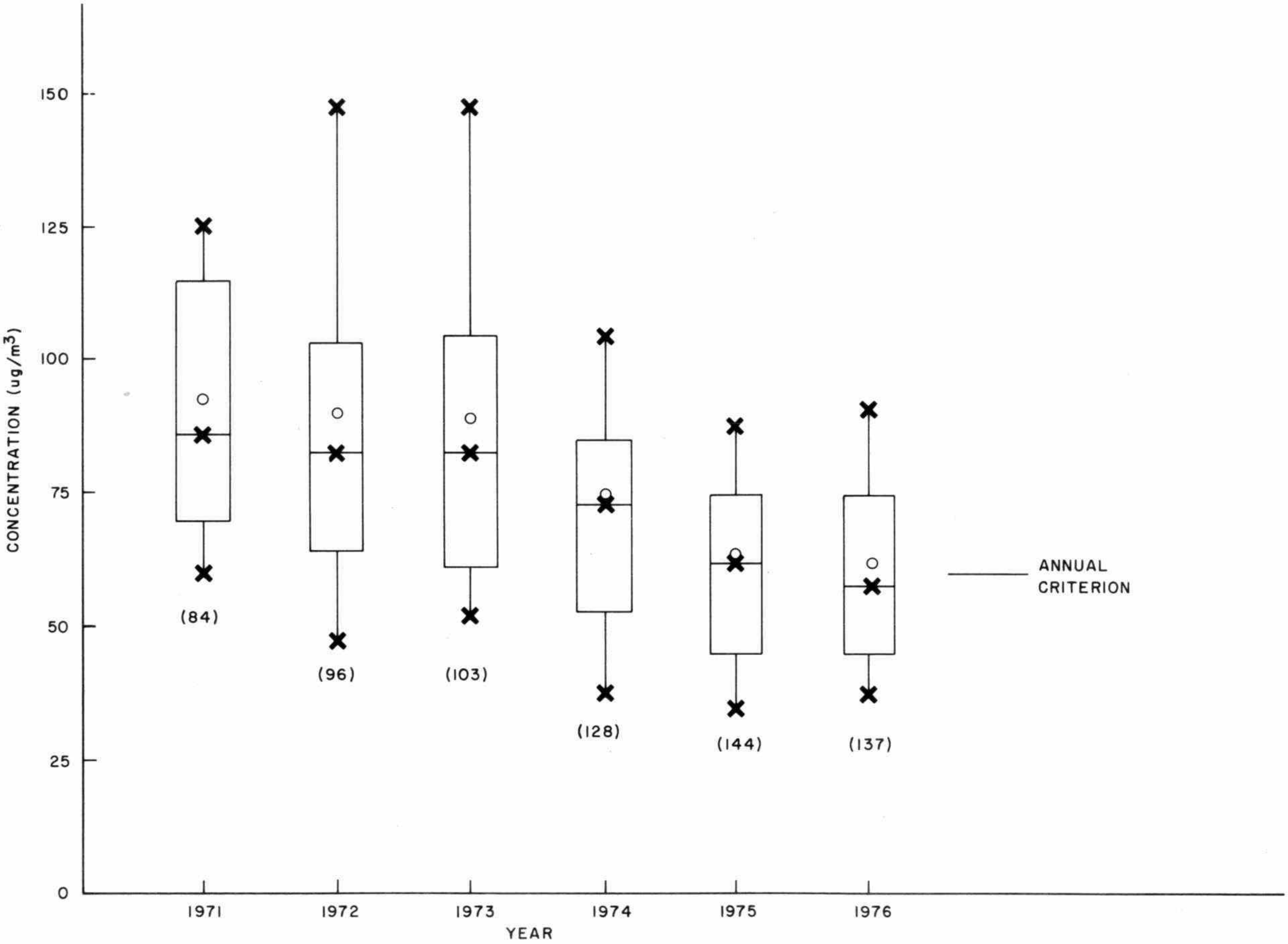

FIGURE 4 TREND OF TOTAL SUSPENDED PARTICULATES IN ONTARIO, 1971 TO 1976

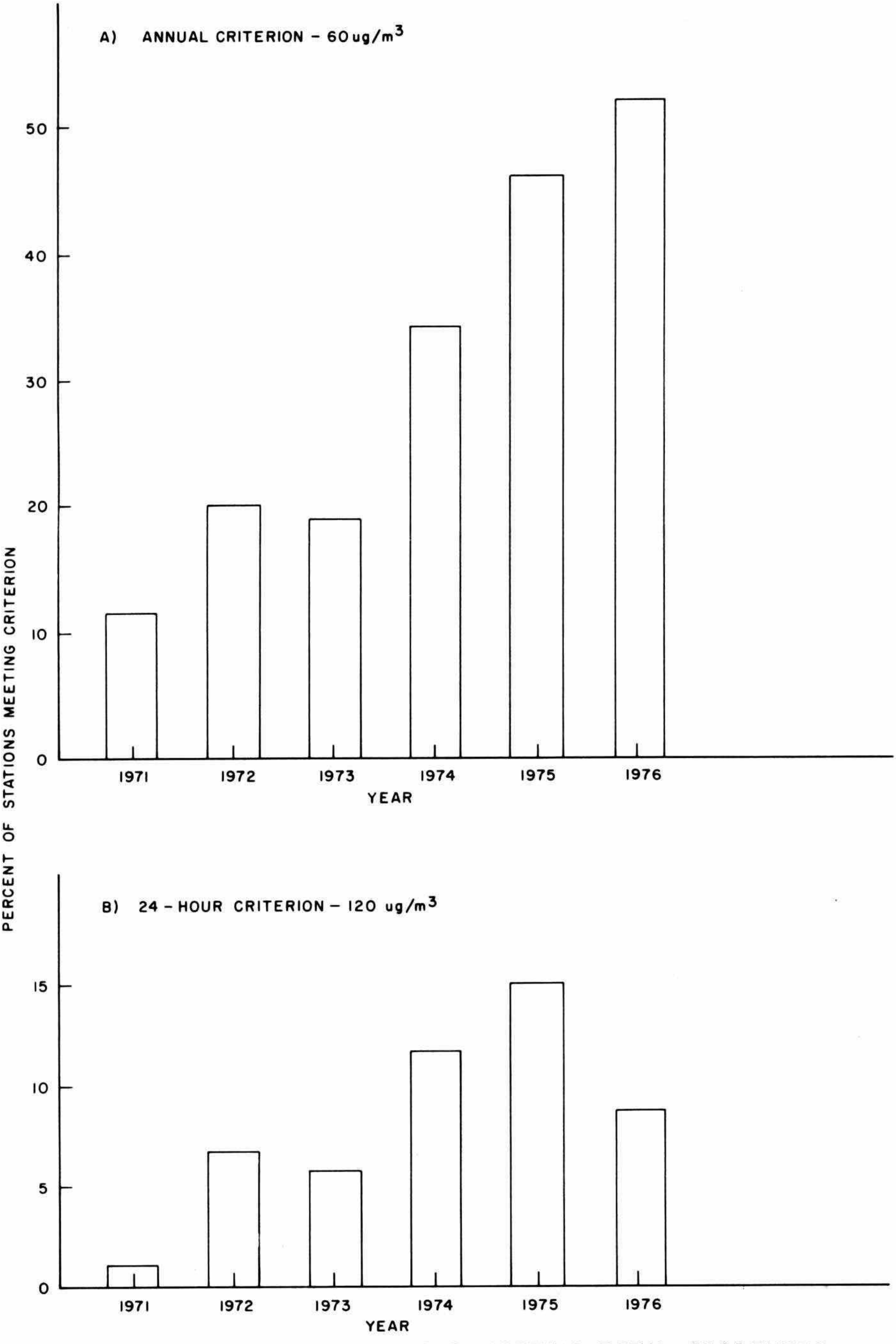

FIGURE 6 PERCENTAGE OF SITES MEETING TOTAL SUSPENDED PARTICULATE CRITERIA IN ONTARIO 1971 TO 1976

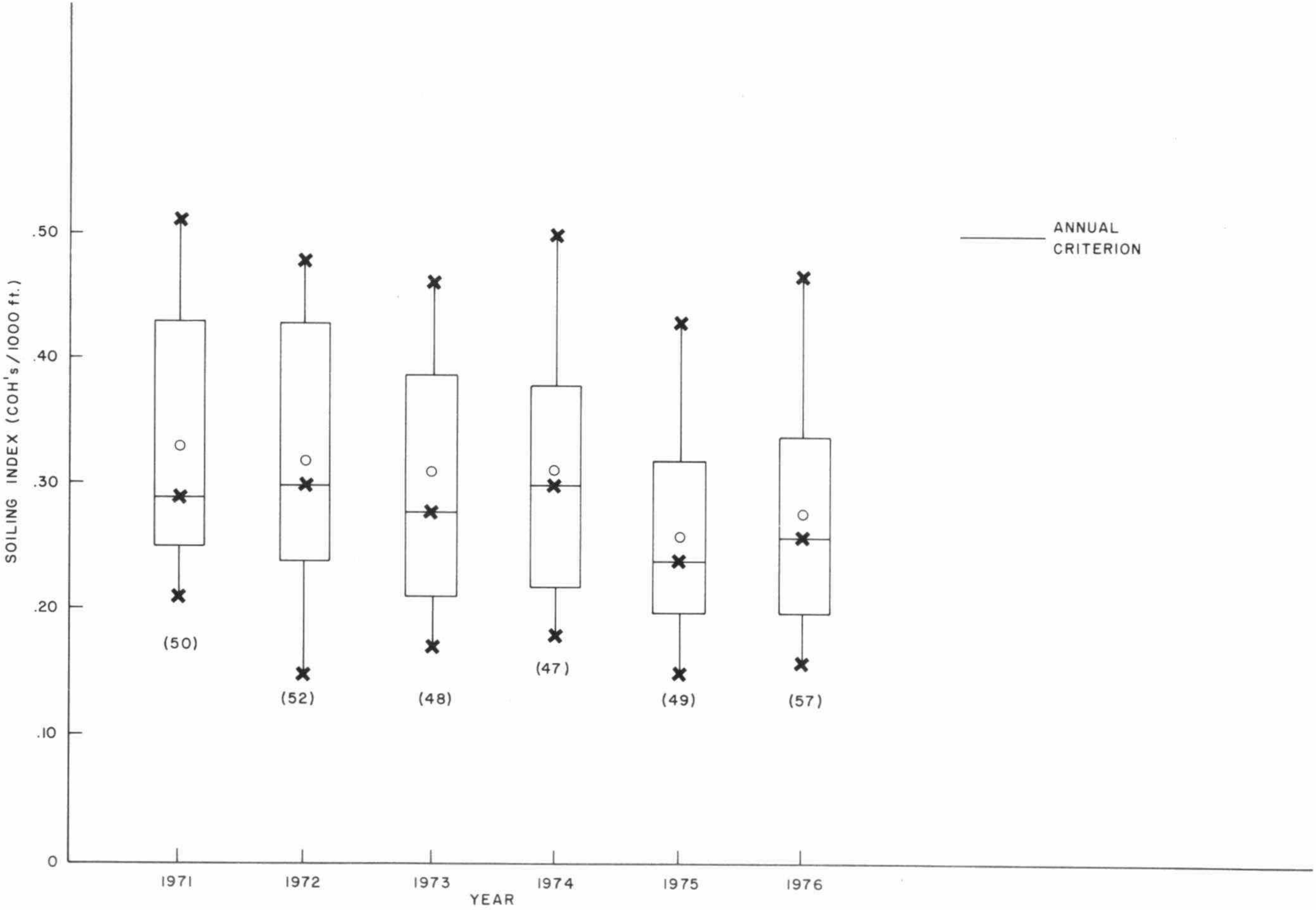

FIGURE 7 TREND OF SOILING INDEX IN ONTARIO, 1971 TO 1976

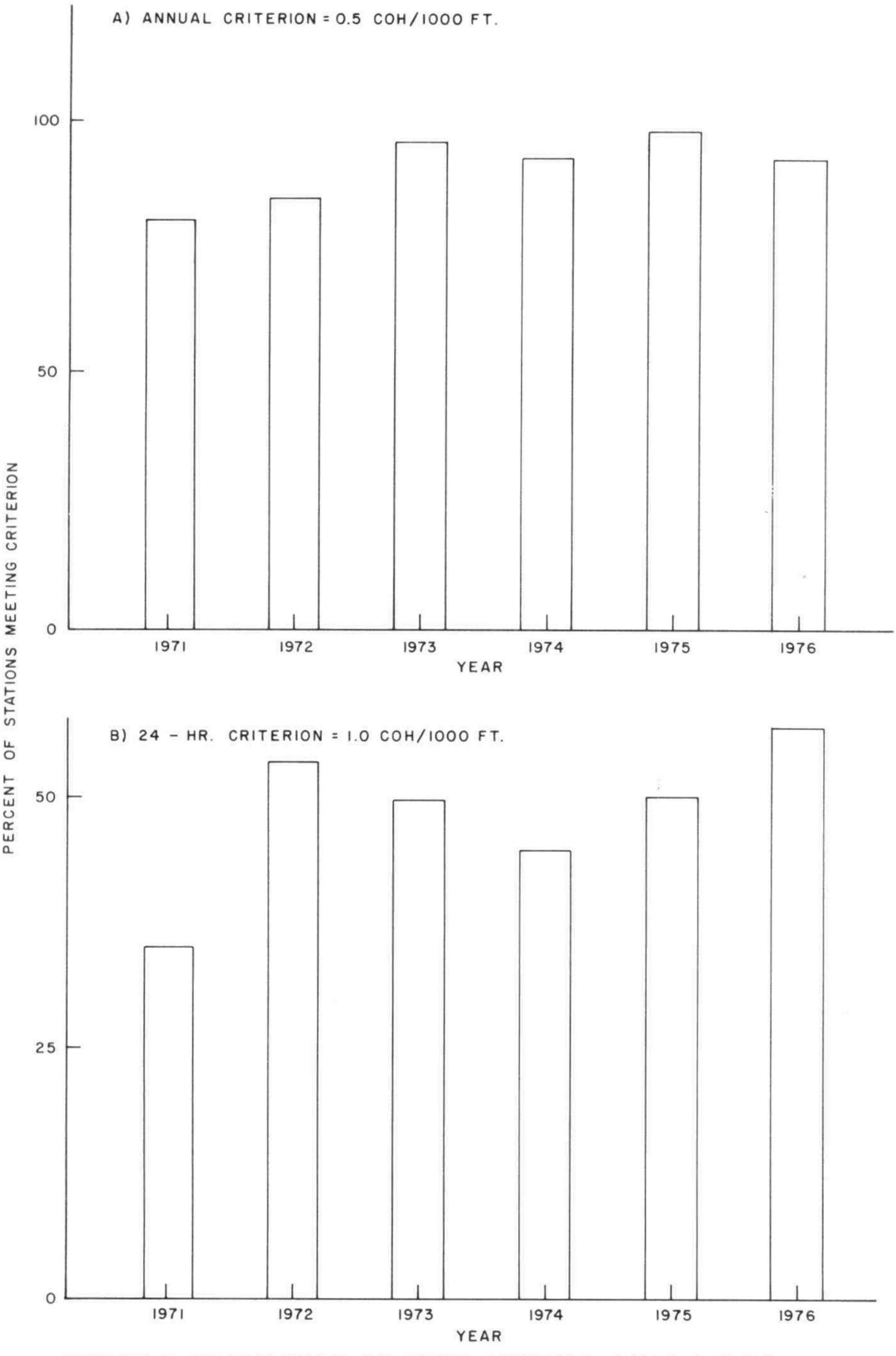

FIGURE 8 PERCENTAGE OF SITES MEETING SOILING INDEX CRITERIA IN ONTARIO, 1971 TO 1976

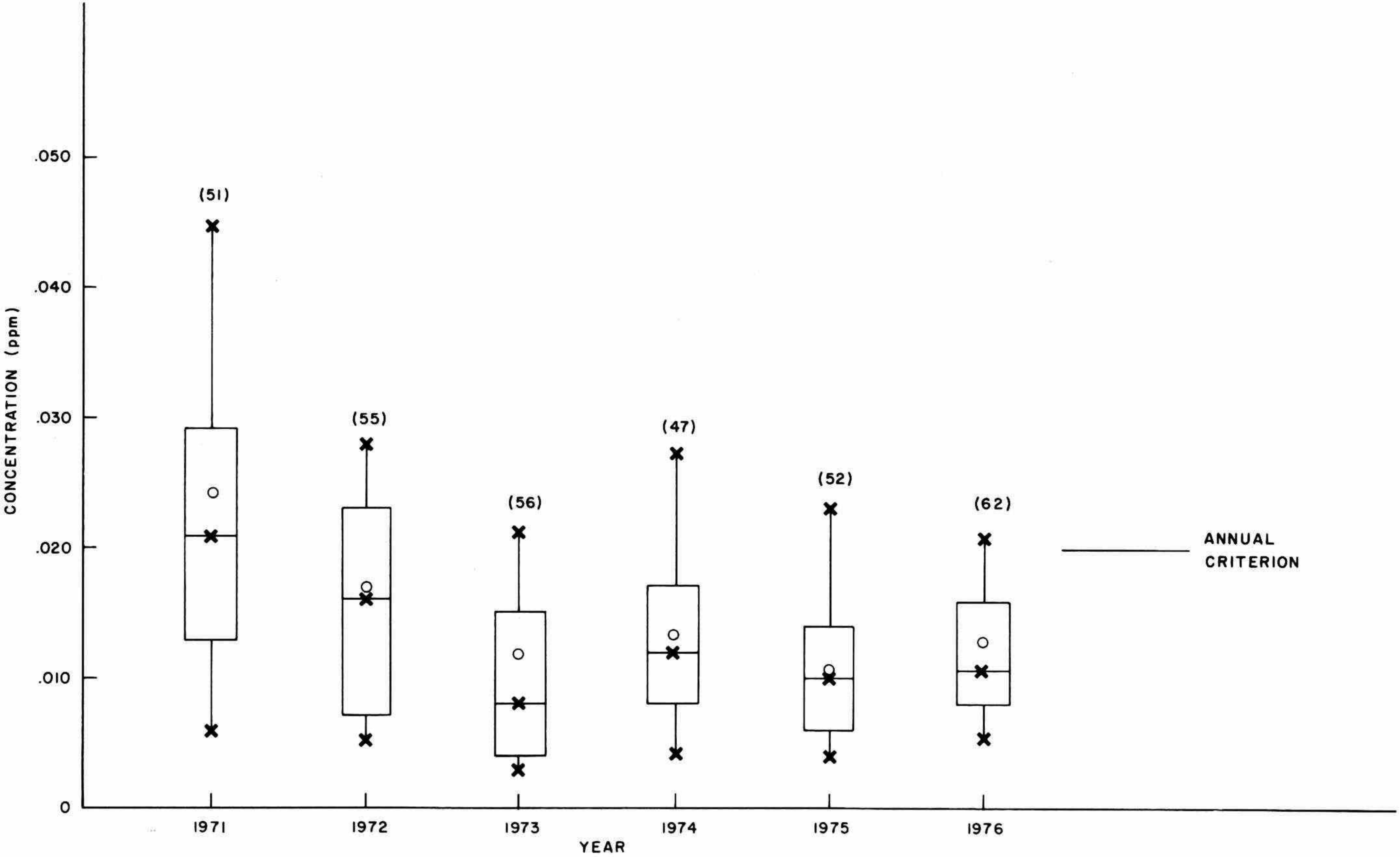

FIGURE 9 TREND OF SULPHUR DIOXIDE IN ONTARIO, 1971 TO 1976

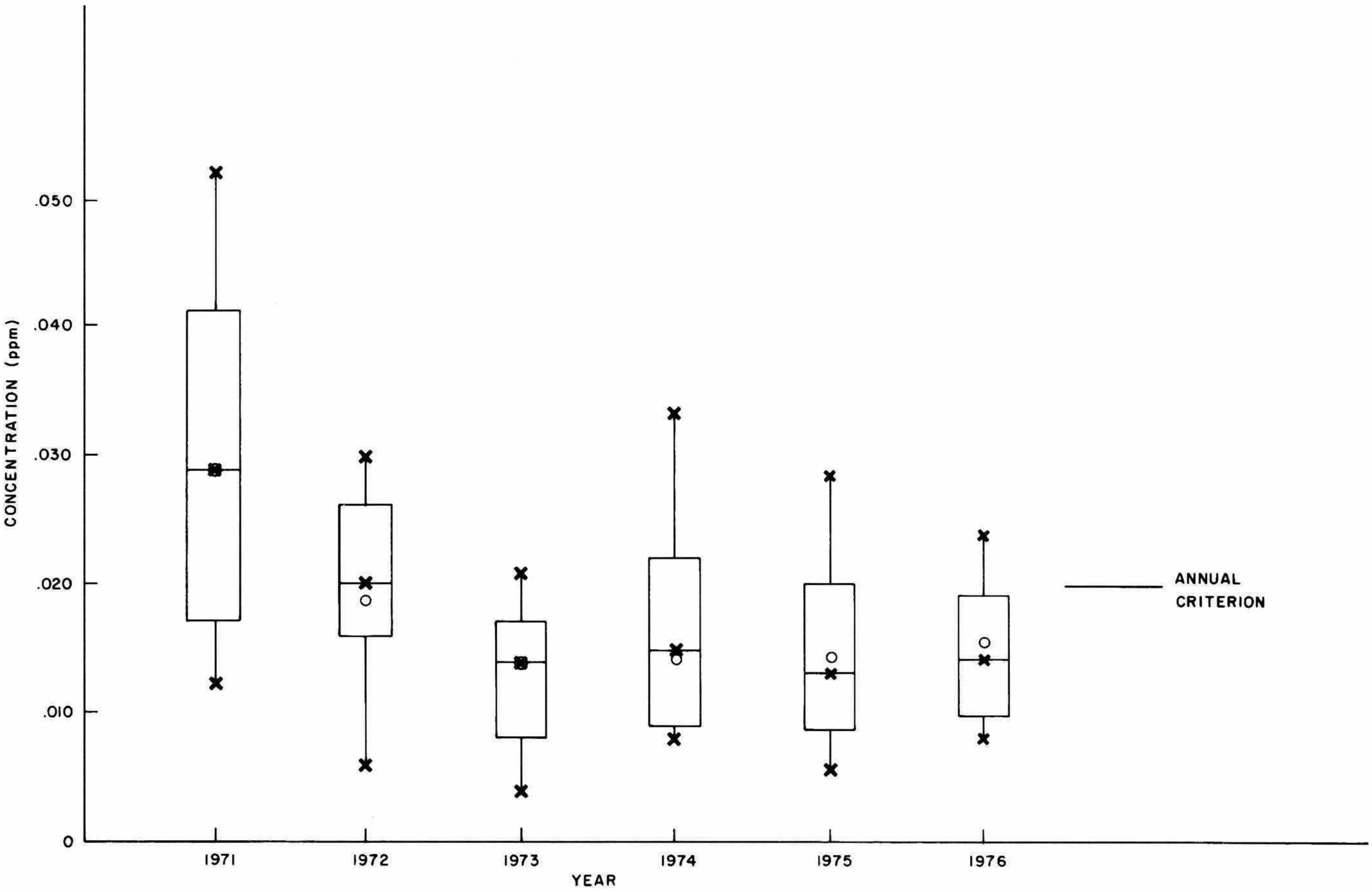

FIGURE 10 TREND OF SULPHUR DIOXIDE IN ONTARIO FOR SELECTED SITES, 1971 TO 1976

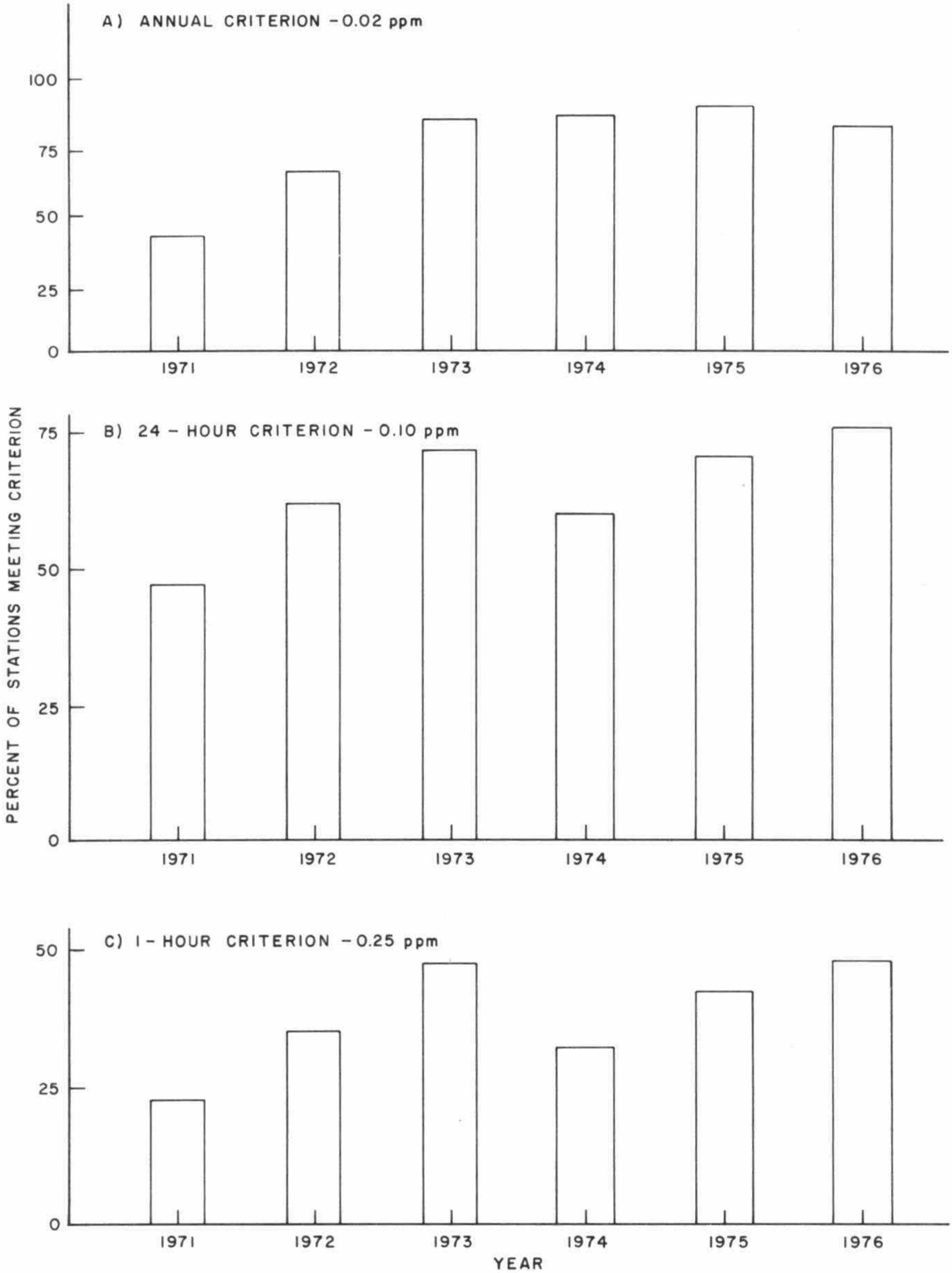

FIGURE II PERCENTAGE OF SITES MEETING SURPHUR DIOXIDE CRITERIA IN ONTARIO, 1971 TO 1976

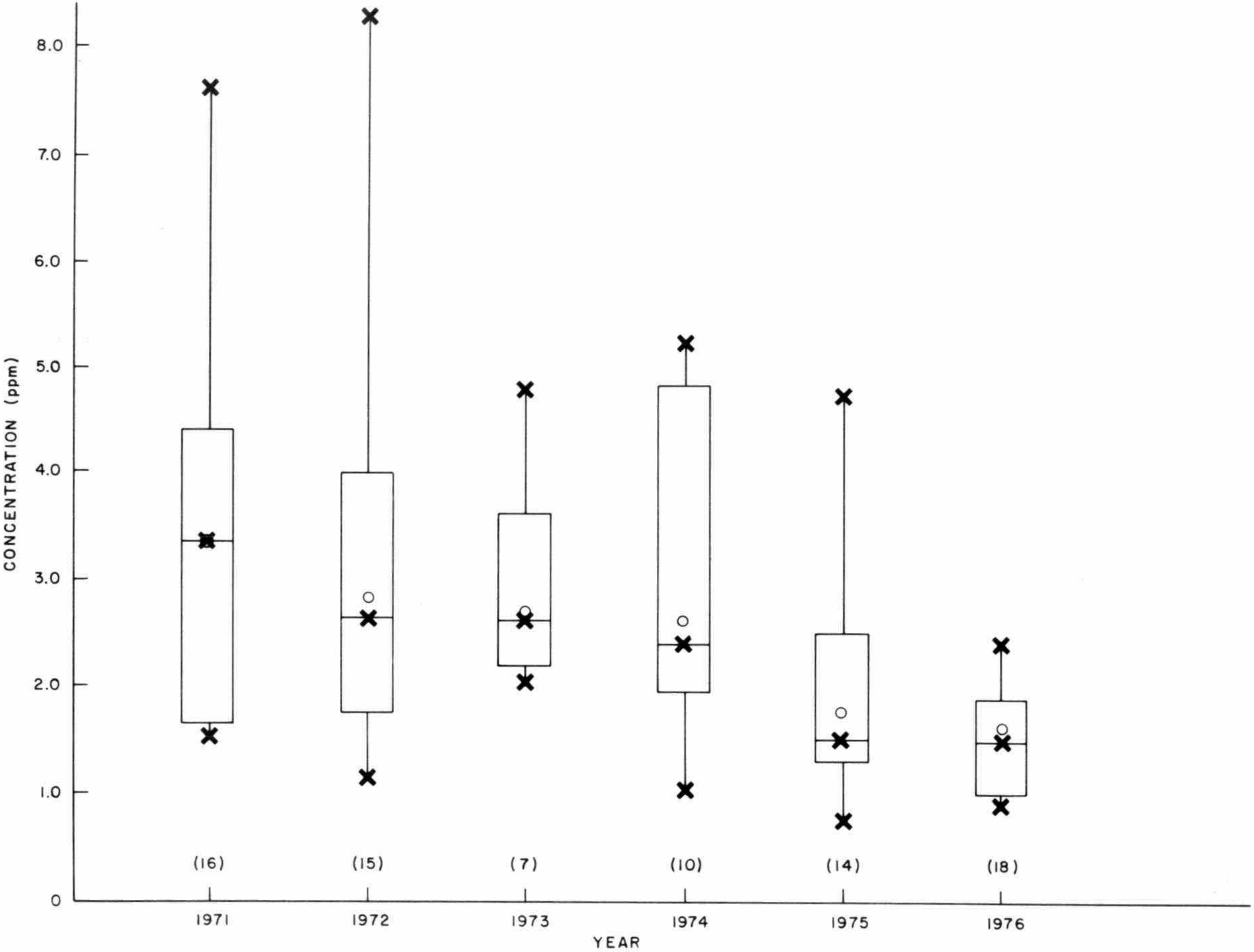

FIGURE 12 TREND OF CARBON MONOXIDE IN ONTARIO 1971 TO 1976

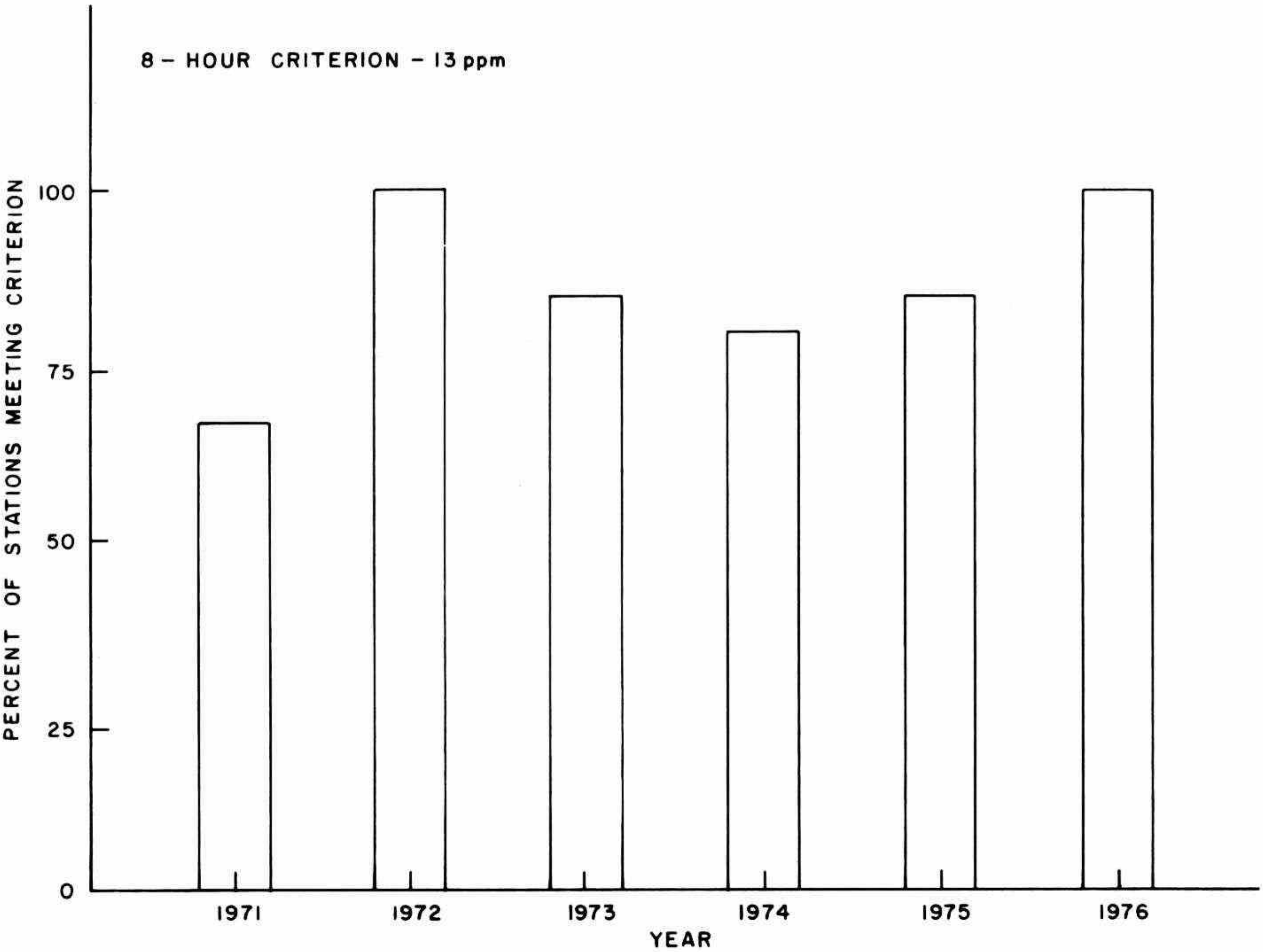

FIGURE 13 PERCENTAGE OF SITES MEETING CARBON MONOXIDE 8-HOUR CRITERION IN ONTARIO, 1971 TO 1976

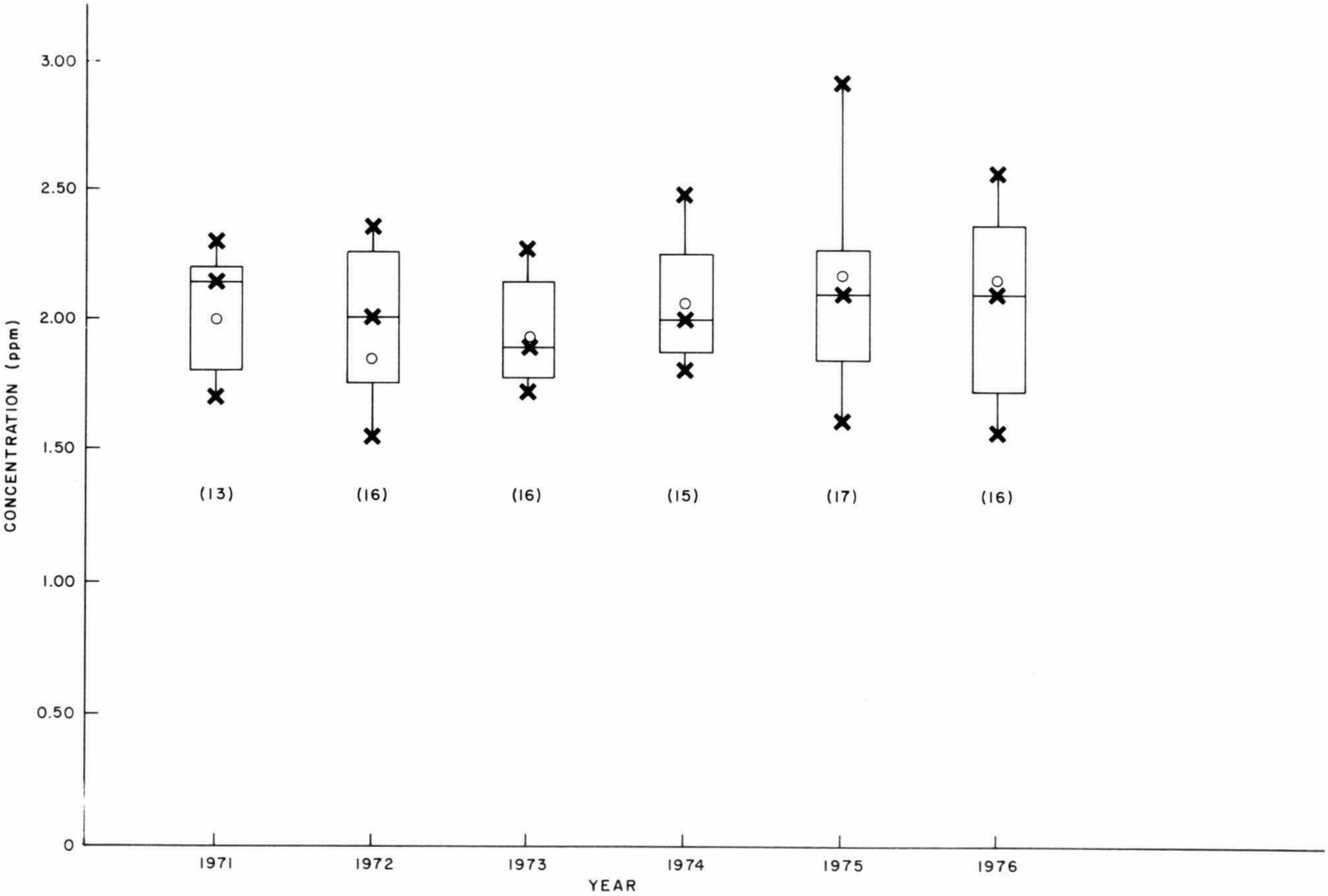

FIGURE 14 TRENDS OF TOTAL HYDROCARBONS IN ONTARIO, 1971 TO 1976

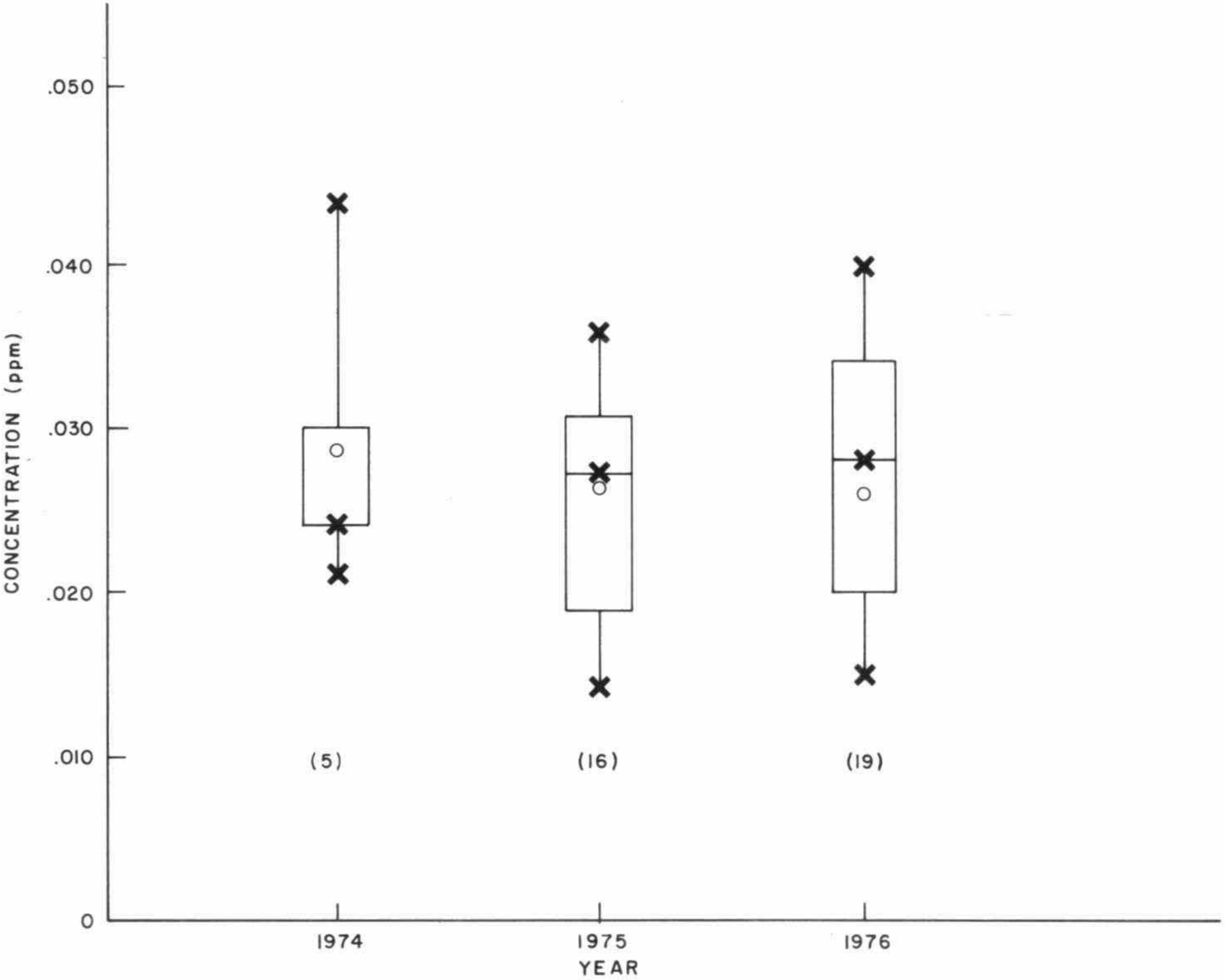

FIGURE 15 TREND OF NITROGEN DIOXIDE IN ONTARIO, 1974 TO 1976

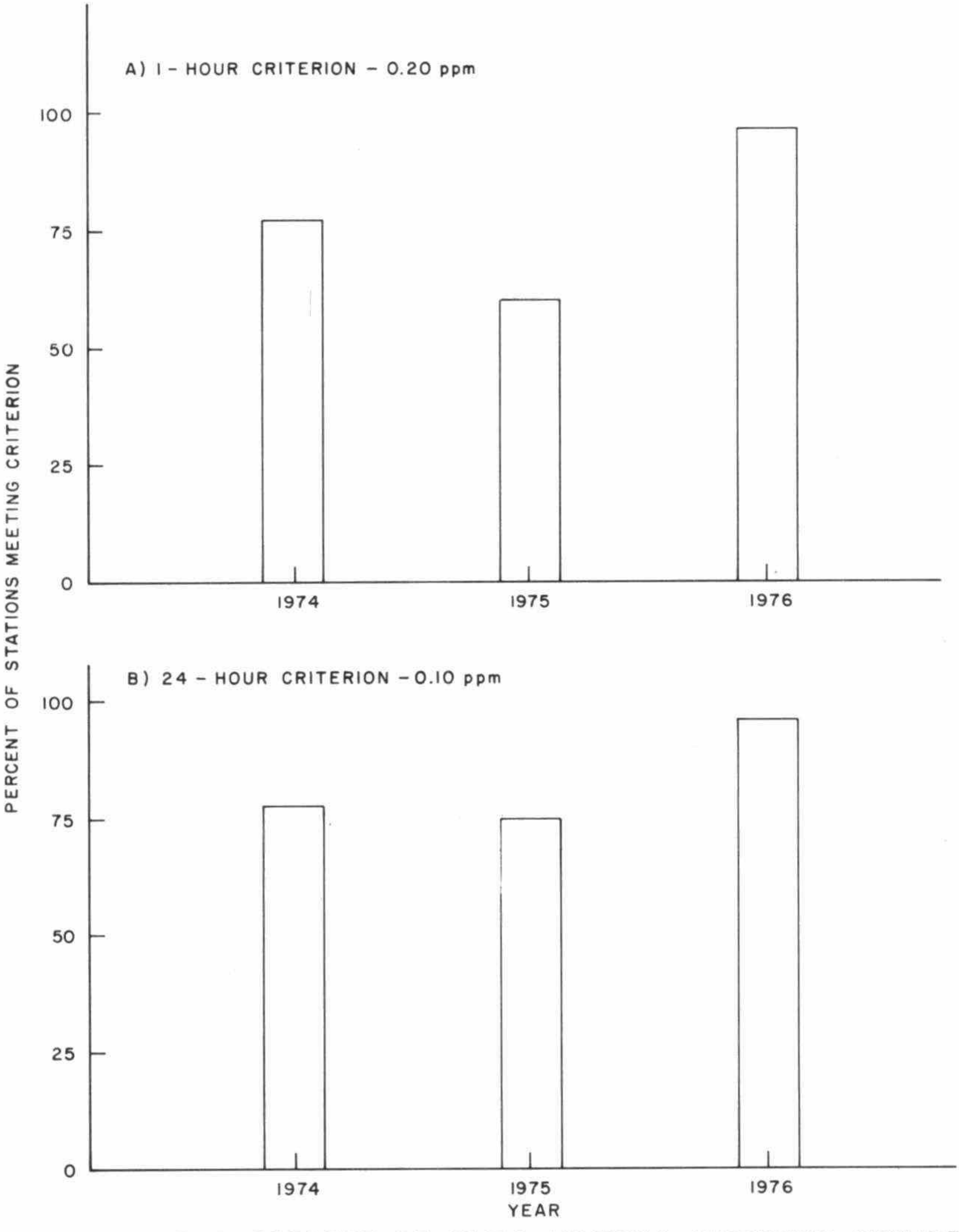

FIGURE 16 PERCENT OF SITES MEETING NITROGEN DIOXIDE CRITERIA IN ONTARIO, 1974 TO 1976

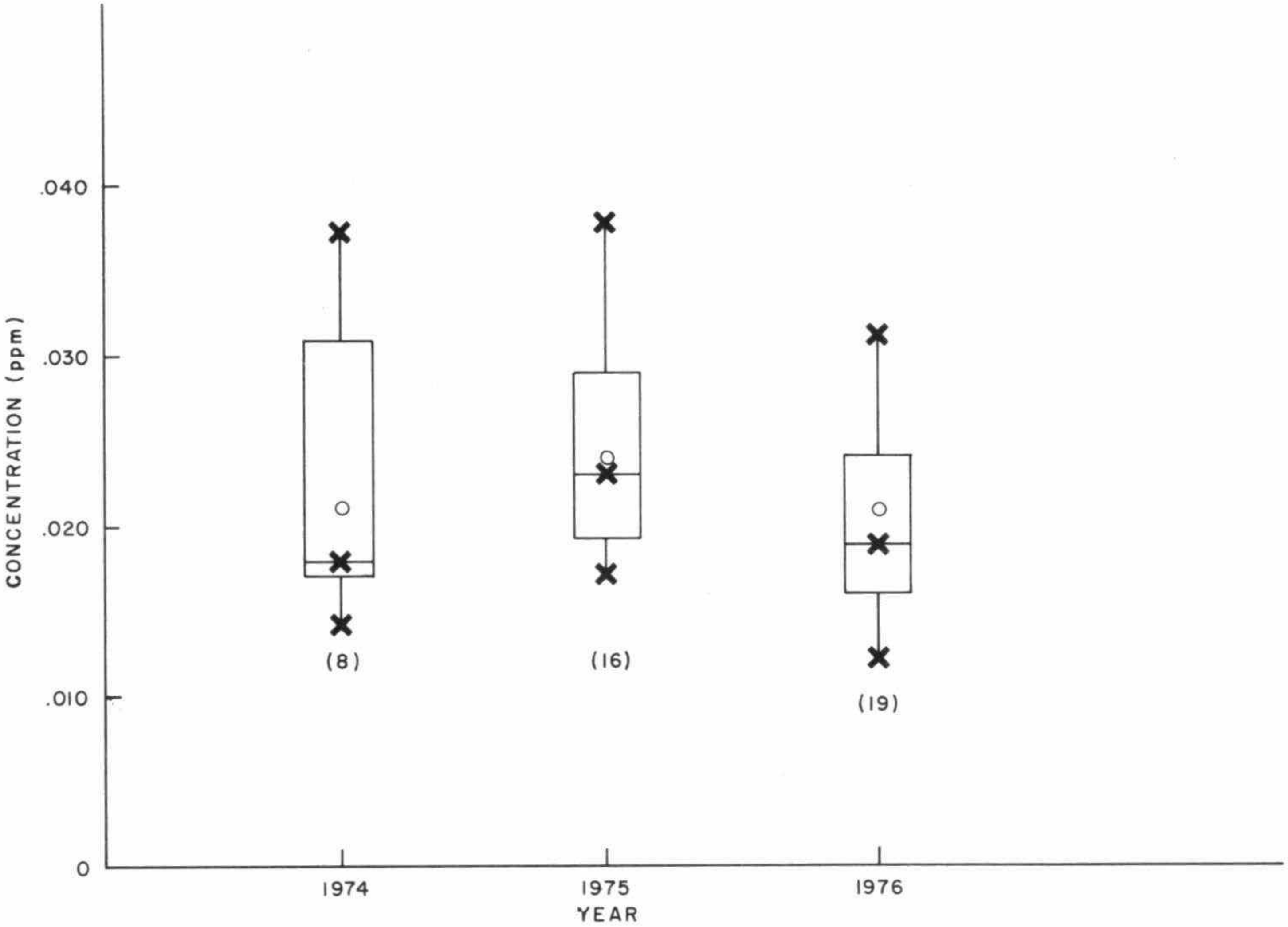

FIGURE 17 TREND OF OZONE IN ONTARIO, 1974 TO 1976

APPENDIX A

ONTARIO AIR QUALITY TRENDS 1971-1976

Pollutant-Year		Number of Sites	Average of Annual Mean	Percentage of sites with annual mean cleaner than given values				
				90%	75%	50%	25%	10%
SO_2	1971	51	0.024	0.045	0.029	0.021	0.013	0.006 ppm
SO_2	1972	55	0.017	0.028	0.023	0.016	0.007	0.005
SO_2	1973	56	0.012	0.021	0.015	0.008	0.004	0.003
SO_2	1974	47	0.013	0.027	0.017	0.012	0.008	0.004
SO_2	1975	52	0.011	0.023	0.014	0.010	0.006	0.003
SO_2	1976	62	0.013	0.021	0.016	0.011	0.008	0.005
CO	1971	16	3.4	7.6	4.4	3.4	1.6	1.5 ppm
CO	1972	15	2.8	8.3	4.0	2.6	1.8	1.1
CO	1973	7	2.7	4.8	3.6	2.6	2.2	2.1
CO	1974	10	2.4	5.2	4.8	2.6	1.9	1.0
CO	1975	14	1.7	4.8	2.5	1.5	1.3	0.7
CO	1976	18	1.6	2.4	1.9	1.5	1.0	0.9
O_3	1974	8	0.021	0.037	0.031	0.018	0.017	0.014 ppm
O_3	1975	16	0.024	0.038	0.029	0.023	0.019	0.017
O_3	1976	19	0.021	0.031	0.024	0.019	0.016	0.012

Pollutant-Year		Number of Sites	Average of Annual Mean	Percentage of sites with annual mean cleaner than given values				
				90%	75%	50%	25%	10%
HC	1971	13	2.00	2.30	2.20	2.10	1.80	1.70
HC	1972	16	1.86	2.33	2.27	1.99	1.76	1.57
HC	1973	16	1.97	2.26	2.12	1.92	1.79	1.74
HC	1974	15	2.07	2.46	2.25	1.99	1.87	1.82
HC	1975	17	2.16	2.90	2.27	2.10	1.87	1.61
HC	1976	16	2.18	2.57	2.38	2.11	1.71	1.56
NO_2	1974	5	0.028	0.044	0.030	0.024	0.024	0.021 ppm
NO_2	1975	16	0.025	0.036	0.031	0.027	0.019	0.014
NO_2	1976	19	0.026	0.040	0.034	0.028	0.020	0.015
Soil	1971	50	0.33	0.51	0.43	0.29	0.25	0.21 COH's/ 1000ft
Soil	1972	52	0.32	0.48	0.43	0.30	0.24	0.15
Soil	1973	48	0.31	0.46	0.39	0.28	0.21	0.17
Soil	1974	47	0.31	0.56	0.38	0.30	0.22	0.18
Soil	1975	49	0.26	0.43	0.32	0.24	0.20	0.15
Soil	1976	57	0.28	0.47	0.34	0.26	0.20	0.16
TSP	1971	84	93.6	125	115	86	69	59 ug/m^3
TSP	1972	96	90.1	144	107	82	65	47
TSP	1973	103	89.8	147	107	82	62	52
TSP	1974	128	74.4	106	85	71	54	39
TSP	1975	144	62.6	89	75	62	46	36
TSP	1976	137	62.0	90	75	58	46	37

Legend: SO_2 - sulphur dioxide; CO - carbon monoxide;
O_3 - ozone; HC - hydrocarbons; NO_2 - nitrogen dioxide; TSP - total suspended particulate; Soil - soiling index.

APPENDIX B

STATIONS EXCEEDING ONTARIO AIR QUALITY CRITERIA 1971-1976

Pollutant-Year		Number of Stations	Stations Exceeding Criterion				Times Criterion Exceeded		
			1-hr.	8-hr.	24-hr.	1-yr.	1-hr.	8-hr.	24-hr.
SO_2	1971	51	40		27	29	2099		264
SO_2	1972	55	36		20	18	1314		148
SO_2	1973	56	30		15	8	732		73
SO_2	1974	47	31		19	6	1111		93
SO_2	1975	52	29		15	5	855		61
SO_2	1976	62	33		15	9	1141		84
NO_2	1974	5	1		1		13		5
NO_2	1975	16	6		4		19		3
NO_2	1976	19	1		1		17		2
CO	1971	16	0	5			0	11	
CO	1972	15	0	0			0	0	
CO	1973	7	1	1			1	1	
CO	1974	10	0	2			0	5	
CO	1975	14	0	2			0	4	
CO	1976	18	0	0			0	0	
O_3	1974	8	8				809		
O_3	1975	16	15				2714		
O_3	1976	19	19				2108		
Soil	1971	50			33	10			249
Soil	1972	52			24	8			174
Soil	1973	48			24	2			232
Soil	1974	47			26	3			246
Soil	1975	49			22	1			148
Soil	1976	57			25	3			176
TSP	1971	84			83	75			1362
TSP	1972	96			89	77			1577
TSP	1973	103			97	83			1850
TSP	1974	128			113	85			2597
TSP	1975	144			122	78			1757
TSP	1976	137			124	66			1999

APPENDIX C

ONTARIO AIR QUALITY MONITORING NETWORK 1971 to 1976

A. Number of Sensors Across Ontario

					Pollutant				
YEAR	TSP	SO_2	SOIL.	(O_x, O_3)	(THC, RHC)	CO	(NO_2, NO, NO_x)	TRS	TOTAL
1971	84	51	50	10	13	16	12	0	236
1972	96	55	52	7	16	15	17	0	258
1973	103	56	48	8	16	7	19	0	257
1974	128	47	47	11	15	10	16	0	274
1975	144	52	49	16	17	14	41	0	333
1976	137	62	57	19	19	18	51	8	371

B. Number of Sensors Across Ontario for Selected Pollutants

YEAR	TSP	SO_2	SOIL.	NO_2	O_3	THC	CO	TOTAL
1971	84	51	50	0	0	13	16	214
1972	96	55	52	0	0	16	15	234
1973	103	56	48	0	2	16	7	230
1974	128	47	47	5	8	15	10	260
1975	144	52	49	16	16	17	14	308
1976	137	62	57	19	19	16	18	328

Legend: TSP - total suspended particulate; SO_2 - sulphur dioxide; Soil. - soiling index; O_x - oxidants; O_3 - ozone; THC - total hydrocarbons; RHC - reactive (non-methane) hydrocarbons; CO - carbon dixoide; NO_2 - nitrogen dioxide; NO - nitric oxide; TRS - total reduced sulphur (expressed as hydrogen sulphide).

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